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# Influence of Plant Density and Application of Different NPK Doses on Growth and Yield Performances of Cucumber (*Cucumis Sativus* L.) under the Open Field Conditions in Kabul, Afghanistan

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## Abstract

The present study was conducted for one growing season from 12th March 2022 to 15th July 2022 in Horticulture Research Farm at Agriculture Faculty of Kabul University in open field, with the specific objective of finding out the interaction influence of three plant density and four NPK doses as a treatment on the growth and yield parameters of Nahid-F1 variety of cucumber. The experiment was laid out following the Factorial Randomized Block Design (FRBD), with three replications consisting of combined three level of plant geometry viz. 75×35 cm (S1), 75×45 cm (S2) and 75×55 cm and four doses of NPK viz., control (F0), 60:30:30 (F1), 80:40:40 (F2) and 120:60:60 (F3) as a treatment. The data on growth attributes and yield contributing characteristics of cucumber crop were recorded and analyzed trough SPSS (22) software (2011) using Analysis of Variance (ANOVA) for Factorial Randomized Black Design (FRBD). The results obtained from the current study reveal that all growth and yield characteristics under the study were remarkably influenced by plant density and dose of NPK and cucumber variety of Nahid-F1 performed better with T12 (75×55 cm + NPK 120:60:60), T8 (75×35 cm + NPK 120:60:60) and T3 (75×35 cm + NPK 80:40:40) in respect to the various growth and yield characteristics, such as number of branches, number of leaves per plant, plant height, stem girth, days to first flower bud initiation, days of first fruits picking, fruit length, fruit girth, average fresh fruit weight, number of fruits per plant, number of fruit per vine, yield per square meter and yield per hectare. While T1 (75×35 cm + control), T5 (75×45 cm + control) and T9 (75×55 cm + control) did not show any superiority in any growth and yield attributes as evaluated in Kabul agro-climatic region. Thus, T8 and T12 could be recommended to the farmers of Kabul province for better cucumber production in Kabul agro-climatic condition in Central Afghanistan.

## Keywords

Cucumber; Growth; Kabul; Plant geometry; Variety; Yield

## Introduction

Cucumber (*Cucumis sativus* L.) is day neutral monoecious annual crop belonging to the Cucurbitaceae family, and it produces both male and female flowers on the same plant on separate nodes (Bist *et al.*, 2020), which comprised of approximately 125 germplasms and 960 species, mainly in tropical and subtropical region (Bist *et al*., 2020; Sadiq *et al.*, 2019). However, some of the genotypes may yield bisexual flowers (Elsheikh and Ahmed, 2005). This indicates that sex appearance in the cucumber plant is influenced by a numbers of environmental factors, such as photoperiod, temperature, plant hormones and genetic make-up (Renner, Achaefer and Kocyan, 2007). Cucumber is believed to have been domesticated in India for 3,000 years and in Eastern Iran and China probably for 2,000 years. It was much appreciated by earliest Greeks and Romans (Sadiq *et al.*, 2019), and it is one of the oldest vegetables cultivated by mankind with historical records dating back 3,000 years (Singh *et al.*, 2019; Eifediyi and Remison, 2010). Cucumber is fourth most vital vegetable after tomato followed by cabbage and onion in Asia and second most important vegetable crop after tomato in Western Europe (Bist *et al.*, 2020; Eifediyi and Remison, 2010). The immature fruits of cucumber are used as salad and for making pickles, *rayata* and brined on commercial scale, consumed either raw as salad, cooked as vegetable, or kept in its unripe stage (Bairagi, Singh and Ram, 2013; Khan *et al.*, 2017). The global production of cucumber is 71.36 million tons (FAOSTAT, 2014; Singh *et al.*, 2019) and commercially it is cultivated in the countries like China, India, Turkey, Iran, Japan, Europe, United States and Afghanistan (Sadiq *et al.*, 2019; Singh *et al.*, 2019). Immature and tender fruits of cucumber are rich in two of the most basic elements required for healthy digestion: fiber and water (Sadiq *et al.*, 2019), but it is very low in energy containing 0.6 g protein, 2.6 g carbohydrate, 12 calories energy, 18 mg Ca, 0.2 mg Fe, 0.02 mg thiamine, 0.02 mg riboflavin, 0.01 mg niacin and 10 mg vitamin C per 100 g of edible portion (Sruthi and Prasad, 2020). The high water content makes cucumber a diuretic and it promotes cleaning action within the body by removing gathered pockets of old waste material and chemical poisons (Sadiq *et al.*, 2019). The high level of potassium and magnesium helps regulate blood pressure, and relaxes nerves and muscles. Ascorbic acid (vitamin C) and coffee acid existing in cucumber lessen skin frustration and swelling. It is said to have cooling effect and avoids constipation (Singh and Kumar, 2012; Sruthi and Prasad, 2020).

Cucumber is a warm season vegetable crop, grown and harvested best in almost all climatic regions around the world (Adinde. *et al.*, 2016; Hochmuth, 2001), ranging from tropical to semi-temperate regions in more than 150 countries with mean temperature of between 25°C to 29°C and plenty of sunlight, over dry and rainy season (Adinde *et al.*, 2016; Hector *et al.*, 2005; Hochmuth, 2001). Cucumber is a frost susceptible horticultural crop, usually cultivated in open fields during spring-summer period or in greenhouse all the year round. While high light intensity causes more male flowers initiation per plant but lower light intensity brings more female flowers per plant (Sadiq *et al*.., 2019). Cucumber grows on a wide range of soil and does best on fertile soil enriched with organic matter having a deep and well-drained sandy loam textures of soil with a pH ranging 5.5 to 6.7 (Ranjian *et al*., 2015), though infertile soil results bitter and misshapen fruits that have little marketability value and are rejected by consumers in the market (Sadiq *et al*., 2019). However, the nutrient demand of the cucumber crop varies depending on soil types, previous cropping

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pattern, native fertility and cultural practices, but it responds positively to organic and inorganic or combined nutrient applications for optimum growth and yield productivity.

The climate of Kabul is deliberated to be continental, cold semi-arid weather with precipitation concentrated in the winter (almost exclusively falling as snow) and spring months, with annual mean temperature of 12.1°C and spring is the wettest season of the year (Belda *et al.*, 2014). From total arable land area in this province is only 6% of rain-fed land, which is available for wheat crops. The fruit crops and vegetables like potato, cucumber, tomato, onion and other seasonal vegetables are grown on the remaining 94% of irrigated farmlands, which are considered as being some of the best quality in Afghanistan. The average farm size in this province is about two *jeribs* (4,000 meter square) and small landowners make up the majority of farming households (FAO, 2007; FAO, 2018). Cucumber cultivation under the open field condition is common in Kabul and its demand is increasing. At present, there are numbers of local and hybrid varieties of cucumber imported by both public and private sectors, but no formal information exists related to their growth, yield and organoleptic performance (FAO, 2016; USAID, 2010). The agro-ecological situation of Kabul province is must suitable for vegetables production particularly for cucumber. Whereas, the low cultivated areas of this crop in Kabul agro-climatic region is due to the various environmental and agronomical factors (Opara *et al.*, 2012; USAID, 2010), and non-availability of proper varieties with high growth and yield performance, climatic situations, edaphic properties, lack of technological knowledge about plant spacing and improper application of fertilizer doses, water shortage for irrigation, plant management and cultural practices in this region (Behzad, Omerkhil and Faqiryar, 2021; Sadiq *et al.*, 2019).

The favorable air temperature, optimum relative humidity, light intensity and auspicious growing season, optimal plant spacing, on time planting and timely irrigation and nutrient supply have a crucial role on the high cucumber yield production (Adinde *et al.*, 2016) and fruit quality. Optimum sowing time brings about proper growth and development of plants resulting in maximum yield of the crop and economic uses of farmland (Sadiq *et al.*, 2019). The plant density and application of different doses of NPK fertilizer influences the vegetative growth and the final yield of cucumber crop (Adinde *et al.*, 2016; Sadiq *et al.*, 2019); plant vegetative growth increased as crop density decreased within rows and column, and cucumber plant disease and pest susceptibility frequently happened in crops with a closest plant spacing among the rows and column (Arif *et al.*, 2019). Dense plants affect the basal internode of cucumber plant, and longer dense plants result in more susceptibility to pest and diseases and low yield compared to the sparse density plants (Opara *et al.*, 2012). Optimal plant density and application of suitable NPK doses are deliberated as a key management element for an effective yield of cucumber, because it is under the farmer's control in most cropping systems and is important in cucumber production (Sadiq *et al.*, 2019; Singh *et al*., 2019). Soil properties, topography, nature of varieties, climatic conditions, and sowing time greatly affect the ideal plant density (Singh *et al.*, 2019). If optimum plant spacing exceeds, final yield decreases often. Earlier, many studies showed that plant spacing significantly influence plant internodes and biological yield (Sadiq *et al.*, 2019; Singh *et al.*, 2019; Sruthi and Prasad, 2020). High amounts of fertilizer compensate for reduced plant vegetative growth improvement

and stimulate more central stem and more fertile flowers, which can be satisfactory, particularly for variety inclined to produce fewer fertile flowers per plant (Singh *et al.*, 2019).

However, no plant density and application of optimal doses of NPK have been identified as best adapted or most suitable for Kabul agro-climatic region, Center Zone, Afghanistan. Hence, the current study focuses on the effect of plant density and dose of NPK on vegetative growth and yield performance of cucumber variety of Nahid-F1 under open field of Kabul region to identifying the best adapted or the most suitable plant density and doses of NPK with the most effective performance for increased yield in Kabul agro-climatic region. This is to be recommended to the farmers for enhanced best quality cucumber production in Kabul agro-climatic region, Center, Zone of Afghanistan, to meet the local and national population's cucumber demands.

## Methodology

To evaluate the influence of plant density and different doses of NPK on vegetative growth and yield performance of cucumber (*Cucumis sativus* L.), the experiment was conducted for one growing season from 12$^{th}$ March 2022 to the 15$^{th}$ July 2022 in research farm of Agriculture Faculty of Kabul University in open field at Kabul, Afghanistan. The site is located in center part of the country at 34° 30' 58" N 69° 08' 13" E with a mean altitude of 1,800 m (Figure 1). The climate of Kabul is considered to be continental, cold semi-arid climate with precipitation concentration in the winter (almost exclusively falling as snow) and spring months with annual mean temperatures of 12.1°C, and spring is the wettest season of the year. The experiment was laid out following Factorial Randomize Block Design (FRBD) with three replications and combination of three levels of plant density viz. 75×35 cm (S1), 75×45 cm (S2) and 75×55 cm and four doses of NPK fertilizer viz., control (F0), 60:30:30 (F1), 80:40:40 (F2) and 120:60:60 (F3) was used as treatments. The experimental field size of 221.4 m$^2$ was marked using measuring tape, rope and peg. Soil samples of experimental field were randomly collected from the site between 0 and 30 cm depth by using soil auger, bulked to make a composite soil samples. The soil samples were analyzed for physio-chemical properties (Table 1). Land clearance was done with the help of cutlass, and the debris was packed using rake. The soil was ploughed to fine tilts using machine plug and harrowing tolls. The experiment field area was marked into three blocks, each block containing three plots of 8.5 m × 3 m and was prepared using a hoe. 0.8 m wide irrigation canals were separated from adjacent blocks and 0.60 m alleys plots, respectively.

Table 1: Physio-chemical analysis of the experimental field soil (2022)

| *Mechanical analysis* | | *Chemical analysis* | |
|---|---|---|---|
| Parameters | Value | Parameters | value |
| Fine Sand % | 53.4 | Organic matter % | 0.47 |
| Course Sand % | 28.4 | EC mmhos/cm$^3$ | 02 |
| Silt % | 7.20 | pH | 8.04 |
| Clay % | 6.13 | Soluble N % | 0.022 |
| Soil texture class | Loam | Available P ppm | 15.85 |
| Bulk density g/cm$^3$ | 1.3 | Exchange K ppm | 6.04 |

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Seeds of cucumber variety were collected from seed market and socked in normal water (18°C) for 20 hours for pre-germination and raising healthy cucumber seedling for open field cultivation. One seed of selected cucumber variety of Nahid-F1 was sown in black polythene bags of 12 cm length and 12 cm girth, filled with mixture of sand: soil: vermicompost (1:2:1) on 20 March. Twenty days old seedlings at 2-3 true leaf stage were transplanted, according to the different treatment combination from polythene bags on 15 April to open field from greenhouse. A steady mechanical weed control of broad and narrow leaf weeds was done at every 10 days' interval with the help of hoe. The agronomical practices including irrigation and hoeing were carried out as per the standard procedure.

Data were collected for 15 different growth attributes and yield contributing characteristics of cucumber crop, such as number of branches per vine, number of leaves per plant, vine length, leaf area, days to first flower bud initiation, days to first fruits picking, and yield characteristics like, fruit length, fruit girth, average fresh fruit weight, number of fruits per vine, fruit yield per plant, yield per square meter and yield per hectare, from six randomly selected middle tagged plants per plot of each treatment. The standard statistical techniques as developed by Steel and Torrie (1980) for factorial experiment in Randomized Block Design (RBD) was adopted for statistical analysis of data recorded, and comparison was made at ($P<0.05\%$) probability level using SPSS (22) software (2011) to compare treatment means.

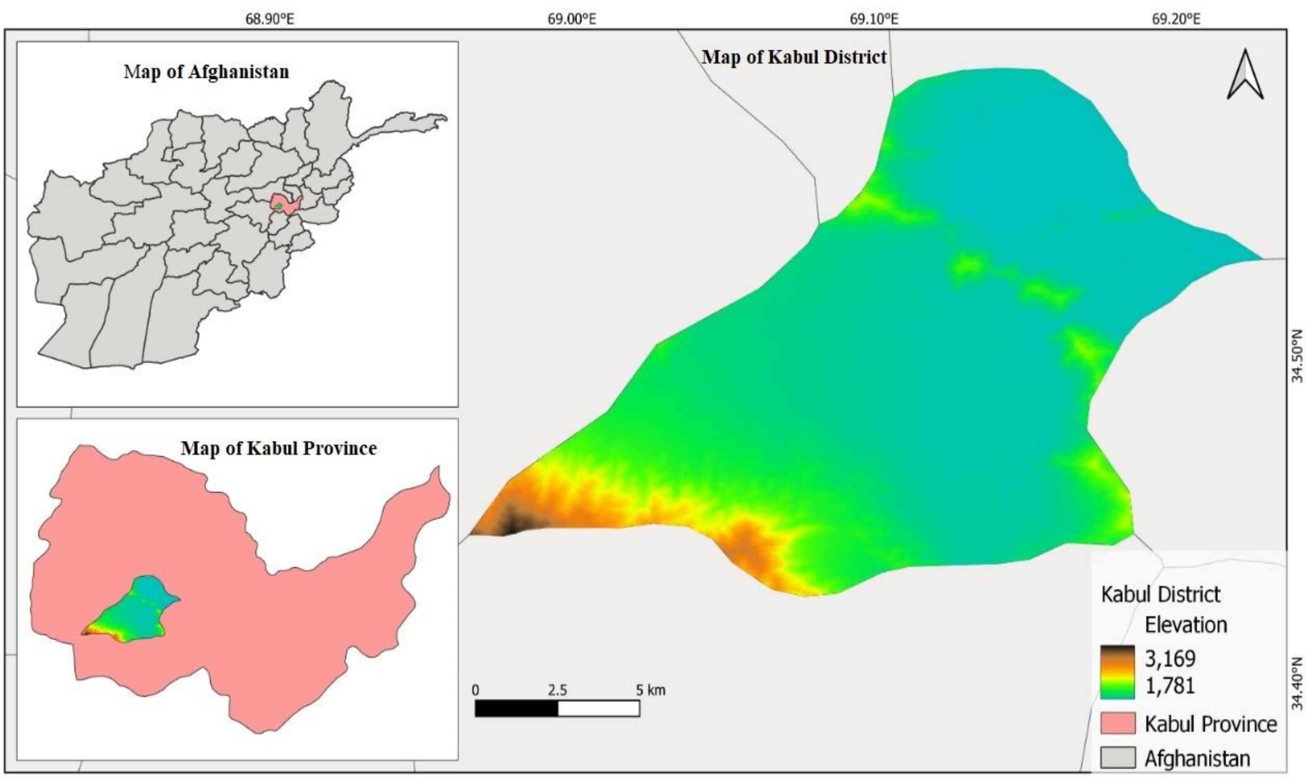


Figure 1: Map of study area (Kabul district, Kabul, Afghanistan)

## Results and Discussion

*Plant Branches*

Number of branches is one of the key characteristics representing cucumber plant's vegetative growth reflecting the effect of agro-chemical and genetic variation. Analysis of variance of the cucumber growth traits under the effects of three plant densities and different doses of NPK are presented in (Table 2). The results revealed significant differences ($p<0.05\%$) due to combination of different doses of NPK and plant densities. T6 (75×35 cm + NPK 60:30:30) produced the highest number of branches per plant (3.45), followed by T3 (75×35 cm + NPK, 120:60:60) i.e. (3.00), T7 (75×45 cm + NPK 80:40:40) i.e. (3.12) and T2 (75×35 cm + NPK, 80:40:40) i.e. (2.93), and the lower with T1 (75×35 cm + control) i.e. (1.14) and T5 (S2, 75×45 + Control) i.e. (2.01), respectively. This may be due to closest plant spacing that may cause high plant population in the current study and low level of NPK since the cucumber variety was the same, which led to competition among plant branches resulting in few branches or flowering buds per plant. Branching stage is mainly controlled by agro-ecological factors and genetic make-up of the variety. The same result of the number of branches per plant was reported by Sruthi and Prasad (2020), Shukla *et al.* (2020) and Singh *et al.* (2019). Better availability of space and higher rates of nitrogen, phosphors and potassium for plant growth seem to have increased the number of branches per plant and it tends to raise the femaleness of cucumber and, thereby, results increased the final yield.

*Number of Leaves per Plant*

The data recorded for the number of leaves per plant showed significant difference ($p<0.05\%$) among all treatments evaluated under this investigation. Among the different treatments, 82.41 leaves per plant was recorded with T7 (75×45 cm + NPK 80:40:40), and T3 (75×35 cm + NPK, 80:40:40) showed the second highest number of leaves per plant, i.e. (73.00). The minimum number of leaves per plant (55.76) was noted in case of T9 (75×55 cm + Control) and T10 (75×55 cm + KPK, 60:30:30), which were statistically in line with other treatments (Table 2). This study observed that a greater number of leaves per plant were generated at the plant density of 75×45 cm with the combination of NPK at the rates of 80:40:40 and the lowest in case of the plant geometry of 75×55 cm combined with control. The greatest number of leaves per plant in plant density of 75×55 cm combined with NPK doses of 80:40:40, i.e. (82.41) was because of the less competition and appropriate plant placement in line. This might be due to the optimum availability of macro-nutrients to boost the number of leaves per plant. Whereas, the plant competition causes fewer number of leaves per plant, a high density of plants per capita provides the situations more prone to disease occurrence and stumpy osmotic pressure among the cucumber plant population. Generally, more number of leaves per plant gives more yields in cucumber. The results of this study are in line with the findings concluding that appropriate placement of plants in line reduces the competition among the plant population having more number of leaves, and enhances the nutrient absorption, vegetative growth, and number of branches per plant and flowering buds, as reported earlier by Sruthi and Prasad (2020), Umamaheswarappa *et al*. (2005) and Singh and Kumar (2012).

*Plant Height*

Plant height is one of the key characteristics representing cucumber plants' vegetative growth reflecting the genetic make-up and agro-eco-technical effect. The results showed that there were significant differences ($p<0.05\%$) among all the treatments combined the plant height, the mean value for this vegetative trait ranges from 173.12 cm to 204.15 cm (Table 2). The plant height in T10 (75×55 cm + NPK, 60:30:30), i.e. (173.12 cm), was significantly shorter than rest of the treatments studied. The plant height was observed maximum (204.15 cm) in T3 (75×35 cm + NPK, 80:40:40) followed by T5 (75×45 cm + NPK, control), i.e. (200.38 cm), T7 (75×45 cm + NPK, 80:40:40), i.e. (198.34 cm), T4 (75×35 cm + NPK, 120:60:60), i.e. (198.33 cm), and T12 (75×55 cm + NPK, 120:60:60). i.e. (199.54 cm), it is significantly higher. The height is lower in plants with T1 (75×35 cm + control) and T10 (75×55 cm + NPK, 60:30:30). Increasing plant spacing significantly influenced plant height, stimulated stem length, and caused higher number of female flower initiation. The plant height of cucumber plant is mainly controlled by genetic make-up of a variety and agro-ecological factors. However, these results are in harmony with the findings of Sruthi and Prasad (2020) who reported that combination of closest plant geometry with different level of NPK increased plant height due to high competition among the plant population. It resulted because of the low level of photosynthesis, more synergistic effect, or their genetic make-up. These results were quite in line with the findings of Singh, Singh and Prasad (2019) and Opara *et al.* (2012), who revealed that cucumber sown at high plant spacing with optimal NPK level produced greater plant height when the shortest plant height was recorded with the closest placement of plant in rows and column.

*Stem Girth*

The present study indicates that there were non-significant differences ($P>0.05\%$) in stem girth of the cucumber sown in combinations of three plant spacing and four doses of NPK fertilizer. The mean value for stem girth laid from 0.72 cm to 0.82 cm, the highest stem girth with a mean value of (0.82 cm) was recorded with the combination of plant density of 75×35 cm and NPK doses of 120:60:60, which was statistically different from the stem girths recorded with treatment combinations of plant geometry and different NPK doses that made T1, T2, T4, T5, T6, T7, T8, T9, T10, T11 and T12. The plant density of 75×55 cm and NPK doses of 80:40:40 had the lowest stem girth with the mean value of (0.72 cm), which was statistically in line with plant spacing of 75×35 cm + control and plant density of 75×55 cm + control. On the other hand, plant spacing of 75×35 cm with combination of NPK doses of 120:60:60 and 75×45 cm with NPK doses of 120:60:60 had second highest mean value (0.78 cm), but was statistically in harmony with the treatments of T2, T4, T5, T7, T8, T10 and T12 (Table 2). This may be due to the availability of more macro-nutrient and suitable spacing for the plants. Generally, the vigorous is the stem the higher is the final yield in cucumber crop. Earlier, similar results were reported by Natsheh and Mausa (2014), Opara *et al.* (2012) and Singh, Singh and Prasad (2019) who reported significant linear increases of stem girth with increased plant spacing, and they indicated that this character was mostly affected by raised level of NPK in cucumber crop.

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*Leaf Area*

When assessing vegetative cucumber leaf area, significant statistical differences ($p<0.05\%$) were detected among the combination of three plant spacing and four different doses of NPK. The average values for the leaf area, ranged from 405.12 $cm^2$ to 412.34 $cm^2$. Plant density of 75×35 cm combined with NPK doses of 60:30:30 produce the maximum leaf area of 412.34 $cm^2$ and, respectively, followed by T11 (75×55 cm + NPK 80:40:40) i.e. (412.23 $cm^2$), T10 (75×55 cm + NPK 60:30:30) i.e. (411.56 $cm^2$), T6 (75×45 cm + NPK 60:30:30) i.e. (406.76 $cm^2$), and T5 (75×45 cm + control) i.e. (408.76 $cm^2$), and minimum was recorded from combined plant density of 75×35 cm with control (405.12 $cm^2$), (Table. 2). Nwofi, Amajouyi and Mhab (2015), Kuranga (2014) and Kumar *et al*. (2017) obtained a lower leaf area with lower doses of NPK and minimum plant spacing due to high density of plant population per capita and plant competition. Supplementary decreases in doses of NPK and plant density would not increase leaf area because the dense plant population will create intense competition between plants for moisture, light and nutrients uptake. In the case of higher NPK level and proper placement of plant in rows, the growth and vegetative improvement of plants were increased due to low competition and equal uptake of essential nutrients and sunlight, which caused high performance of cucumber crop leaf area and finally increased the cucumber final yield (Opara *et al.*, 2012; Singh, Singh and Prasad 2019).

*Days to First Flower Bud Initiation*

The observation recorded for days to first flower bud initiation showed significant statistical differences ($p<0.05\%$) among the combined plant density and NPK doses studied. The minimum days to first flower bud initiation (40.92 DAS) was recorded with T7 (75×45 cm + NPK 80:60:60) followed by T6 (75×45 cm + NPK 60:30:30), i.e. (41.31 DAS), T11 (75×55cm + NPK 80:40:40), i.e. (41.87 DAS), and T9 (75×55 cm + control) i.e. (41.87 DAS). The maximum days required for first flower bud initiation was reported in T5 (75×45 cm + control), (43.16 DAS) followed by T3 (75×35 cm + NPK 80:40:40), i.e. (42.95 DAS), T12 (75×55 cm + NPK 120:60:60), i.e. (42.12 DAS) and T1 (75×35 cm + control). The greater number of days for first flower bud initiation in maximum plant geometry and highest amount of NPK was because of the increased vegetative growth and more production of vine and leaves per plant. While the plant competition causes less flower bud initiation per plant, a high population of plants per capita makes condition prone to osmotic pressure among the plant population and disease outbreak. This study is in harmony with the findings of Eifediyi and Remison (2010), Umamaheswarappa *et al.* (2005), Kumar *et al.* (2017) and Natsheh and Mausa (2014), who concluded that nutrient absorption is more due to reduced competition among the plant population enhancing vegetative growth and increased number of days to first flower bud initiation.

*Days of First Fruit Picking*

The present study shows that the days of first fruits picking was also significantly affected by the plant density and NPK doses ($p<0.05\%$). Minimum number of days required to first fruit harvest (52.13 DAS) was recorded with T8 (75×45 cm + NPK 120:60:60) followed by T4 (75×35 cm + NPK120:60:60), i.e. (52.65 DAS), T3

(75×35 cm + NPK 80:40:40), i.e. (53.13 DAS), T6 (75×45cm + control), i.e. (53.22 DAS), and T11(75×55 cm + NPK 80:40:40), i.e. (53.11 DAS), which was statistically at par with each other. While the maximum days to first fruit picking was recorded with T9 (75×55 cm + control), i.e. (57.43 DAS), T1 (75×35 cm + control), i.e. (56.43 DAS), T10 (75×55 cm + NPK 60:30:30), i.e. (55.23 DAS), T2 (75×35 cm + NPK 80:40:40), i.e. (55.24 DAS), T5 (75×45 cm + control), i.e. (54.13 DAS), and T7 (75×45 cm + NPK 80:40:40), i.e. (54.23 DAS). The result reveals that the highest number of days to first fruit picking in minimum plant spacing and unavailability of macronutrient is due to decreases in plant vegetative and reproductive growth. Availability of macronutrients (NPK) and proper plant density promote the first fruit picking of cucumber crop, whereas low level of plant density combined with reduced NPK rate has major reverse effect on the vegetative and reproductive growth of the cucumber plant. The findings of this study contradict the results of several other researches done by Singh, Singh and Prasad (2019), Eifediyi and Remison (2010) and Khan *et al.* (2017). Application of optimal NPK level and plant density decreased the deterioration chance in plant vine and late improvement of cucumber fruits in plant; otherwise, in the situation of plant branches worsening, final fruit yield is also reduced.

Table 2: Effect of plant density and NPK rates on the growth components of cucumber crop (*Cucumis sativus* L.) under the open field

| *Treatment combinations* | *No. of branches/ plant* | *No. of leaves/ plant* | *Plant height (cm)* | *Stem girth (cm)* | *Leaf area ($cm^2$)* | *Day to first flower bud initiate (DAS)* | *Days of first fruits picking (DAS)* |
|---|---|---|---|---|---|---|---|
| S1+F0 (T1) | 1.14 | 58.17 | 178.67 | 0.73 | 405.12 | 42.23 | 56.43 |
| S1+F1 (T2) | 2.93 | 58.33 | 191.76 | 0.75 | 412.34 | 42.13 | 55.24 |
| S1+F2 (T3) | 3.00 | 73.00 | 204.15 | 0.82 | 408.05 | 42.95 | 53.13 |
| S1+F3 (T4) | 1.38 | 61.17 | 198.33 | 0.78 | 406.18 | 42.67 | 52.65 |
| S2+F0 (T5) | 2.01 | 66.67 | 200.38 | 0.76 | 408.76 | 43.16 | 54.13 |
| S2+F1 (T6) | 3.45 | 61.50 | 187.10 | 0.74 | 406.76 | 41.31 | 53.22 |
| S2+F2 (T7) | 3.12 | 82.41 | 198.34 | 0.75 | 411.65 | 40.97 | 54.23 |
| S2+F3 (T8) | 2.16 | 61.43 | 191.45 | 0.77 | 405.91 | 42.17 | 52.13 |
| S3+F0 (T9) | 1.98 | 55.76 | 185.38 | 0.73 | 406.17 | 41.87 | 57.43 |
| S3+F1 (T10) | 1.78 | 57.41 | 173.12 | 0.76 | 411.56 | 42.13 | 55.23 |
| S3+F2 (T11) | 2.01 | 58.12 | 197.32 | 0.72 | 412.23 | 41.13 | 53.11 |
| S3+F3 (T12) | 1.99 | 67.01 | 199.54 | 0.74 | 407.13 | 42.14 | 54.98 |
| F- test | * | * | * | NS | * | * | * |
| S.Ed. (±) | 0.26 | 0.058 | 0.005 | 0.002 | 0.04 | 0.103 | 0.071 |
| CD at 5% | 0.89 | 0.118 | 0.010 | 0.004 | 0.09 | 0.209 | 0.144 |

Note: *= (Critical variation); S.Ed = Standard Error division; NS; Non-significant and CD; critical different at (P<0.05%).

*Fruit Length*

The data recorded for the fruit length showed significant variability (p>0.05%) among the all treatments combined. The highest fruit length (19.42 cm) was recorded with

T12 (75×55 cm + NPK 120:60:60), and it was statistically superior than the rest of the combinations of planting geometry and NPK doses, followed by T8 (75×45 cm + NPK 120:60:60) i.e. (19.30 cm), T7 (75×45 cm + NPK 80:40:40) i.e. (18.10 cm), T6 (75×45 cm + NPK 60:30:30) i.e. (17.00 cm) and T3 (75×35 cm + NPK 80:40:40) i.e. (17.20 cm). However, the lowest fruit length was observed in T9 (75×55 cm + control), i.e. (15.14 cm), and were statistically at par with T2 (75×35 cm + NPK 60:30:30) i.e. (15.78 cm) and T1 (75×35 cm + control) i.e. (15.30 cm). The high plant distances combined with raised doses of NPK gradually improved the fruit length in cucumber. The results showed that the cumulative consequence of yield influencing characteristics, such as effective fresh fruit yield, fruit weight and final yield per hectare had a positive impact on increased fruit length that achieved from 75×55 cm plant spacing and 120:50:60 NPK doses. Application of optimal NPK dosages is very important for the vegetative growth and high yield of cucumber. In the case of higher plant spacing and increased NPK doses, the growth and vegetative improvement of cucumber plants were increased due to low competition and equal uptake of essential nutrients among the plant population, which caused high performance of cucumber crop yield traits and finally increased the fruit yield. The results of this study are in harmony with the findings of Sruithi and Prasad (2020), Singh *et al.* (2019), Singh and Kumar (2012) and Garawany and Albaloushi (2015), as they concluded that plant spacing and optimal nutrients application for the vegetable are two important factors to increase the productivity and final yield. Optimum amount of fertilizers causes improved growth and yield, if the fertilizer doses increase from its recommended rate and the leaching of nutrient, soil degradation, etc. may take place.

*Fruit Girth*

The interaction of plant density and NPK doses on fruit girth of the evaluated Nahid-F1 cucumber variety showed significant statistical differences at $p<0.05\%$ probability level. The mean value for this yield attribute laid from 16.97 cm to 13.32 cm (Table 3). The highest girth with a mean value of 16.97 cm was recorded in T8 (75×45 cm + NPK dosed of 120:60:60), which was statistically different from the fruit girth recorded with rest of the combined treatments for this yield characteristic. The plant density of 75×35 cm combined with control had minimum fruit girth with the mean value of 13.32 cm, which was statistically in consonance with T2 (75×35cm + NPK 60:30:30) i.e. (14.33 cm), T5 (75×45cm + control) i.e. (14.38 cm) and T9 (75×55 cm + control) i.e. (14.32 cm). On the other hand, T12 (75×55 cm + NPK 120:60:60) had second highest mean value of 16.87 cm, but was statistically different with T8 (75×45 cm + NPK 120:60:60) i.e. (16.79 cm). To determine yield and yield component and physical properties of cucumber fruits, plant density and nutrient supply from soil are considered two important agriculture practices. Generally, the more vigorous is the fruit the higher is the yield in cucumber crop. Earlier, similar finding was reported by Kuranga (2014), Singh and Kumar (2012), Garawany and Albaloushi (2015) and Bist *et al.* (2020). Nutrients from mineral fertilizers enhance the establishment of crops, while optimal plant spacing promoted fruit girth and yield when both fertilizers and plant spacing were combined.

*Average Fresh Fruit Weight*

Due to variation in plant density and NPK doses, the average fresh fruit weight was significantly different (p<0.05%) in the current investigation. The maximum fresh fruit weight was found in T8 (75×45 cm + NPK 120:60:60) i.e. (313.17 g), statistically identical to T3 (75×35 cm + NPK 80:40:40) i.e. (305.08 g), T12 (75×55 cm + NPK 120:60:60:60) i.e. (313.12 g) and T4 (75×35 cm + NPK 120:60:60) i.e. (291.63 g). The minimum fresh fruit weight of 213.92 g was recorded from T1 (75×35 cm + control) (Table 3). Likewise, T12 (75×55 cm + NPK 120:60:60) had the second highest average fresh fruit weight valuing 313.12 g, but was statistically at par with T4 (75×35 cm + NPK 120:60:60) i.e. (291.63 g) and T3 (75×35 cm + NPK 80:40:40) i.e. (305.08 g). However, there was statistically non-significant difference (p>0.05%) between T11 (75×55 cm + NPK 80:60:60) and T5 (75×45 cm + control) applied in this study. The mean values for interaction of different plant densities and NPK doses revealed that treatments T8 (75×45 cm + NPK 120:60:60) and T12 (75×55 cm + NPK 120:60:60) were optimal for agro-ecological situation in Kabul. The present study showed that the plant spacing and NPK optimal rate has a key role in the yield and improvement of fruit fresh weight and its final weight. A similar findings of plant geometry and NPK rate on the average fresh fruit weight of cucumber were also been reported by Adinde *et al.* (2016), Bist *et al.* (2020), Khan *et al.* (2017), Ahmed *et al.* (2007) and Garawany and Albaloushi (2015), as their findings indicate that NPK doses and plant spacing play an important role in determination of quality and quantity of cucumber fruit. NPK fertilizer reaches directly to the root zone of plant and increases the vegetative growth and fruit yield, but application of proper NPK doses and plant spacing management will be necessary with many of agricultural practices, especially irrigation method and its time interval.

*Number of Fruits per Plant*

The data recorded for the number of fruits per plant shows significant statistical differences (p<0.05%) resulting from some plant geometry and NPK combinations. The maximum number of fruits per plant (21.80) was observed with T12 (75×55 cm + NPK 120:60:60) followed by T8 (75×45 cm + NPK 120:60:60) i.e. (21.58) and T3 (75×35 cm + NPK 80:40:40) i.e. (21.12), which were statistically at par with each other. While the lowest number of fruits per plant (16.78) was recorded in plants sown at the plant density of 75×35 cm + control), it was the same with the plant density of (75×45 cm + NPK 60:30:30), (75×45 cm + control) and (75×55 cm + control) (Table 3). The result reveals the lowest number of fruits per plant in T5 (75×45 cm + control) i.e. (17.65), T6 (75×45 cm + NPK 60:30:30) i.e. (17.01) and T9 (75×55 cm + control) i.e. (17.43) showing more competition due to improper NPK placement. The cucumber plant requires fertile soil and enough space. Infertile soil and close space result low initiation of female flowering bud that cause low number of fruits per plant. Optimal plant spacing and NPK rate have a significant influence on the vegetative improvement of the plant at the same time at reproductive stage. Its role is more considerable, which is why different levels of NPK and plant density affect the number of fruits per plant significantly. Total number of fruits per plant showed positive significant relationship with vine length and number of flowers per plant. Bist *et al.* (2020), Khan *et al.* (2017), Ahmed *et al.* (2007), Eifediyi and Remison (2010) and Khan *et al.* (2017) also reported the number of fruits per plant varied significantly

with variation in plant geometry and NPK rates, and biotic and abiotic stresses are the main factors responsible for low yield and poor quality under open field cultivation. This variability may be due to the unsuitable placement of plant in rows and columns and minimum availability of NPK nutrients.

*Number of Fruits per Vine*

The results related to number of fruits per vine as influenced by various NPK levels and plant densities are given in table 3. Both plant spacing and their interaction with NPK levels demonstrated highly significant difference ($p<0.05\%$). The highest mean value (14.23) of fruits per vine was recorded in T11 (75×55 cm + NPK 80:40:40), followed by T3 (75×35 cm + NPK 80:40:40) i.e. (14.20) and T8 (75×45 cm + NPK 120:60:60) i.e. (14.00), which was statistically at concordance with each other. The lowest number (11.23) of fruits per vine was noted in T9 (75×55 cm + control), which was in line with T5 (75×45 cm + control) i.e. (11.75) and T1 (75×35 cm + control) i.e. (11.66). Over all, plant density of 75×55 cm + NPK doses of 80:40:40 had greater number of fruits per vine (1,423) as compared to the rest of the two plant densities and three NPK doses. However, the nutrient and spacing requirements of the crop vary depending on the native fertility, soil type, previous cropping and cultural practices. It is concluded that number of fruits per vine significantly increased, as the plant spacing between rows was increased and optimal level of NPK applied. Proper plant density and application of NPK rates promotes the initiation of flowering bud that resulted in increased number of fruits per vine; but decreased NPK rates and plant geometry reduced the number of fruits due to improper vegetative development of cucumber crop as witnessed in case of plant elevation. The results of this study are in the close conformity with the findings of Nwofia, Amajouyi and Mbah (2015), Khan *et al.* (2017), Bist *et al.* (2020) and Khan *et al.* (2017) who reported that cucumber rarely grows luxuriantly in close plant spacing and reduced level of NPK. Hence, its level of susceptibility to poor soil fertility and improper placement of plants between rows and columns manifests in the form of low vegetative growth, decreases in initiation of flowering bud that resulted in low number of fruits set per vine. On the other hand, raised level of NPK and plant density increases the number of fruits due to proper vegetative development of cucumber crop as witnessed in case of plant elevation in cucumber crop.

*Fruit Yield per Plant*

The present study reveals that the fruit yield per plant was also significantly affected by the combination of plant spacing and NPK doses at $p<0.05\%$. The average value for this characteristic of cucumber crop laid between 1.67 kg to 2.84 kg (Table 3). Treatment three, (75×45 cm + NPK 120:60:60) produced maximum fruit yield per plant (2.84 kg), and it was statistically superior to the rest of the treatments. Minimum fruit yield per plant (1.67 kg) was registered in T1 (75×35 cm + control). The second-high mean value of fruits yield per plant was observed in T4 (75×35 cm + NPK 120:60:60) i.e. (2.73 kg) and T7 (75×45 cm + NPK 80:40:40) i.e. (2.73 kg). Statistically, it was at par with T8 (75×45 cm + NPK 120:60:60) i.e. (2.84 kg). The mean value of fruit yield per plant gradually improved with increased plant density and NPK doses. The findings of this trail showed that the cumulative consequence of yield influencing attributes, such as effective vine length, number of branches per

plant, number of fruits per plan, fruit diameter, fruit length and fresh fruit weight having a positive influence on increased fruit yield per plant achieved from the interaction of plant density of 75×45 cm with NPK rates of 120:60:60. In the case of application of lower NPK rates and closest plant spacing, the growth and vegetative enhancement of plants were reduced due to high competition and unequal uptake of macro-nutrients, which caused poor performance of cucumber crop yield attributes and ultimately decreased the fruit yield per plant (kg). The results of this study corroborate the findings reported by Khan *et al.* (2017), Nwofia, Amojouyi and Mbah (2015) and Singh and Singh Prasad (2019). Combination of nitrogen, phosphate, potash and plant spacing are important and play a key role on vegetative growth and fruit yield than other nutrients and cultural practices, as it promotes the rapid growth of roots, vegetative parts, setting of flowers, blooming setting and cucumber crop yield attributes, ultimately increasing the fruit yield per plant in cucumber crop.

*Yield per Square Meter*

Documented results of the data recoded for yield per square meter of combined three plant density and four NPK doses studied are presented in table 3 and vary significantly ($p<0.05\%$) amongst in all treatments. The average value related to this character ranged from 11.01 kg to 13.77 kg. 13.77 kg is the higher yield per square meter of cucumber variety Nahid-F1 sown in T8 (75×45 cm + NPK 120:60:60) was statistically identical to T3 (75×35 cm + NPK 80:40:40) i.e. (13.46 kg), T11 (75×55 cm + NPK 80:40:40) i.e. (13.43 kg) and T12 (75×55 cm + NPK 120:60:60) i.e. (13.37 kg). It was minimum (11.01 kg) in T9 (75×55 cm + control) compared to the other treatments studied in this study. It was statistically similar to T5 (75×45 cm + control), T6 (75×45 cm + NPK 60:30:30) and T1 (75×35 cm + control). These results showed the optimal plant spacing and NPK doses for this trait in Kabul agro-climatic situation for two combinations (75×45 cm + NPK 80:40:40 and 75×55 cm + 120:60:60). The proper plant density and NPK doses have a crucial role and are responsible for cucumber crop yield attributes increase ultimately the quality, quantity and weight per meter square. The findings of this study are pretty in line with the results of Natsheh and Mausa (2014), Opara *et al.* (2012), Kumar *et al.* (2017) and Sing and Kumar (2012) who concluded that optimal planting space and NPK doses increased significantly the yield attributes, like plant elevation, number of branches, number of female flower per plant, fruit diameter, fresh fruit weight, and fruit weight per plant. This ultimately increased the quantity and yield (kg) per square meter of cucumber crop.

*Yield per Hectare*

The mean value recorded for yield per hectare showed a vital difference ($p<0.05\%$) among the combined treatments under the study. The data for yield per hectare depicted a linear upward rise with the increases in plant spacing and NPK doses (Table 3). Different plant spaces and NPK doses in cucumber crop showed variability in yield per hectare significantly. Maximum yield per hectare (69.65 t/ha) was observed from the T8, which was made from the combination of plant density of 75×45 cm + NPK doses of 120:60:60. In comparison, minimum yield (47.40 t/ha) was recorded from the treatment with combination of plant spacing of 75×35 cm + control, which was statistically identical to the T6 (75×45 cm + NPK 60:30:30) i.e. (57.21

t/ha), T5 (75×45 cm + control) i.e. (59.20 t/ha) and T9 (75×55 cm + control) i.e. (58.56 t/ha). The results of this study reveal that the yield per hectare progressively improved with the increased level of plant density and NPK rates. The average value for this parameter indicated that the cumulative influence of yield contributing traits, such as adequate number of branches per vine, vine length, number of fruits per plant and yield per square meter, had effective influence on higher yield per hectare obtained from T8 (75×45 cm + NPK 120:60:60). In the case of closest plant spacing and reduced NPK rates, the growth and enlargement of cucumber plant were exposed due to high competition of uptake of vital nutrients and sunlight. It has caused depleted yield attributes and finally culminated in the most minor yield per hectare. Earlier, similar results for final yield per hectare were also reported by Tiwari and Mishra (2013), Adinde *et al.* (2016), Bist *et al.* (2020), Khan *et al.* (2017), Ahmed *et al.* (2007) and Garawany and Albaloushi (2015). Optimal NPK rates and proper plant density had an influential role on different biochemical and physiological processes resulting in more yield production per capita in cucumber crop. But, reduced NPK rates and closest plant density cause high competition for the uptake of vital nutrients and sunlight for physiological process and caused depleted yield attributes and finally culminating in the most minor yield per hectare.

Table 3: Interaction effect of plant densities and NPK doses on some yield characteristic of cucumber crop (*Cucumis sativus* L.) under open field situation

| *Treatment combinations* | *Fruit length (cm)* | *Fruit girth (cm)* | *Average fresh fruit weight (g)* | *No. fruit/ plant* | *No. fruits/ vine* | *Fruit yield per plant (kg)* | *Yield per square meter (kg)* | *Yield per hectare (t/ha)* |
|---|---|---|---|---|---|---|---|---|
| S1+F0 (T1) | 15.30 | 13.32 | 213.92 | 16.78 | 11.66 | 1.67 | 11.13 | 47.40 |
| S1+F1 (T2) | 15.78 | 14.33 | 272.13 | 19.65 | 13.68 | 2.58 | 12.86 | 62.50 |
| S1+F2 (T3) | 17.20 | 15.30 | 305.08 | 21.12 | 14.20 | 2.56 | 13.46 | 69.21 |
| S1+F3 (T4) | 16.60 | 16.21 | 291.63 | 20.62 | 13.23 | 2.73 | 12.93 | 68.86 |
| S2+F0 (T5) | 16.10 | 14.38 | 218.21 | 17.65 | 11.75 | 1.98 | 11.56 | 59.20 |
| S2+F1 (T6) | 17.00 | 15.57 | 247.56 | 17.01 | 12.84 | 2.00 | 11.78 | 57.21 |
| S2+F2 (T7) | 18.10 | 16.79 | 287.01 | 18.35 | 13.67 | 2.73 | 12.01 | 61.34 |
| S2+F3 (T8) | 19.30 | 16.97 | 313.17 | 21.58 | 14.00 | 2.84 | 13.77 | 69.65 |
| S3+F0 (T9) | 15.14 | 14.32 | 267.32 | 17.43 | 11.23 | 1.87 | 11.01 | 58.56 |
| S3+F1 (T10) | 16.01 | 14.78 | 254.37 | 19.07 | 12.32 | 1.98 | 12.98 | 57.43 |
| S3+F2 (T11) | 16.42 | 15.65 | 231.76 | 18.21 | 14.23 | 1.87 | 13.43 | 63.13 |
| S3+F3 (T12) | 19.42 | 16.87 | 313.12 | 21.89 | 13.35 | 2.67 | 13.37 | 69.32 |
| F- test | * | * | * | * | * | * | * | * |
| S.Ed. (±) | 0.102 | 0.180 | 0.212 | 0.058 | 0.175 | 0.041 | 0.101 | 0.034 |
| CD at 5% | 0.228 | 0.014 | 0.432 | 0.118 | 0.355 | 0.083 | 0.204 | 0.068 |

Note: *= (Critical variation); S.Ed = Standard Error division; NS; Non-significant and CD; critical different at (P<0.05%).

## Conclusions`and Recommendations

Cucumber (*Cucumis sativus* L.) is one of the oldest vegetable crops belonging to the Cucurbitaceae family, which comprised of approximately 125 genera and 960 species (Bist *et al.*, 2020; Sadiq *et al.*, 2019). This crop is the fourth most important vegetable

after tomato, cabbage and onion in Asia (Eifediyi and Remison, 2010). This experiment was designed to identify the best adapted combination of plant density and doses of NPK with the most effective performance for increased yield of cucumber variety of Nahid-F1 under the open field of Kabul region. The results acquired from the current study reveal that the application of various plant density, namely, 75×35 cm (S1), 75×45 cm (S2) and 75×55 cm and different doses of NPK fertilizer viz. control (F0), 60:30:30 (F1), 80:40:40 (F2) and 120:60:60 (F3), remarkably influenced all growth attributes and yield characteristics of cucumber variety of Nahid-F1. The result indicated that T12 (75×55 cm + NPK 120:60:60) and T8 (75×35 cm + NPK 120:60:60) performed better in respect to the various growth and yield characteristics, such as number of branches per plant, number of leaves per plant, plant height, stem girth, days to first flower bud initiation, days of first fruits picking, fruit length, fruit girth, average fresh fruit weight, number of fruits per plant, number of fruits per vine, yield per square meter and yield per hectare. While T3 (75×35 cm + NPK 80:40:40) were the second best treatment after the T12 and T8. However, T1 (75×35 cm + control), T5 (75×45 cm + control) and T9 (75×55 cm + control) did not show any superiority in any growth and yield attributes of cucumber crop as evaluated in Kabul agro-climatic region. Therefore, T8 (75×35 cm + NPK 120:60:60) and T12 (75×55cm + NPK 120:60:60) can be recommended to the farmers of Kabul province for better and more profitable cucumber production in Kabul agro-climatic condition in central Afghanistan.

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## Authors' Declarations and Essential Ethical Compliances

*Authors' Contributions (in accordance with ICMJE criteria for authorship)*

| *Contribution* | *Author 1* | *Author 2* | *Author 3* |
|---|---|---|---|
| Conceived and designed the research or analysis | Yes | Yes | No |
| Collected the data | Yes | No | No |
| Contributed to data analysis & interpretation | Yes | Yes | Yes |
| Wrote the article/paper | Yes | Yes | Yes |
| Critical revision of the article/paper | Yes | Yes | Yes |
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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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